Role of Interfacial Crystallization in Understanding Structure-Property Relationships in Polyolefin Blends

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Objective:

Determine how the processing method affects blend architecture and mechanical properties of polyethylene/polypropylene blends.

Introduction:

- Polyethylene (PE) and polypropylene (PP) are the two highest volume produced polymers in the world[1].
- Despite being chemically very similar hydrocarbons, PE and PP are immiscible and experience low interfacial adhesion[2,3], limiting recycling and other practical applications of the mixture of polymers.
- Catalyst selection, impacting the polymer chain distribution, could improve the interfacial adhesion between these polymers[4].
- PP/PE adhesion increases by 20-fold[4] when Ziegler-Natta catalyzed polymers are replaced with metallocene catalyzed polymers.
- It may be possible to increase interfacial area by creating micron scale droplets in blended samples of the polymers.

Materials:

xyZ

- x → Catalyst: m = metallocene; z = Ziegler-Natta
- y → Architecture: i = isotactic; h = high density; l = linear low density
- Z → Polymer: E = polyethylene; P = polypropylene

Blend Preparation:

- Extruded blend sheets and compression molded blends were prepared
- Extruded blends prepared by twin screw extrusion
  - Kneading blocks and forward conveying elements mix the materials
  - Specified ratios: 0, 25, 50, 75, 100 % PE
- Extruded sheets were also pelletized for further processing

Prism Twin Screw Extruder

Prism Pelletizer

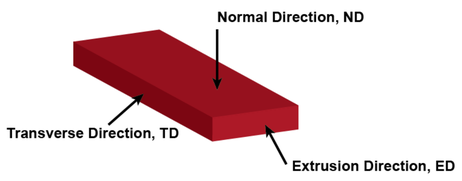
- Compression molded blends were prepared
- Blended pellets were placed in molds and hot pressed for 5 minutes at 180 °C

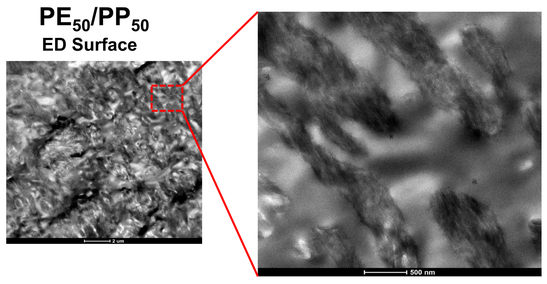
Carver Hot Press

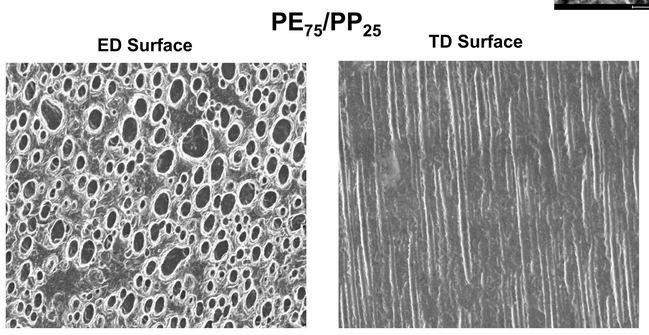
Morphology: Samples were cryo-microtomed and etched to remove polypropylene before imaging

Extruded Blend Sheets – Imaging

- Co-continuous morphology was observed at PE_{50}/PP_{50} composition

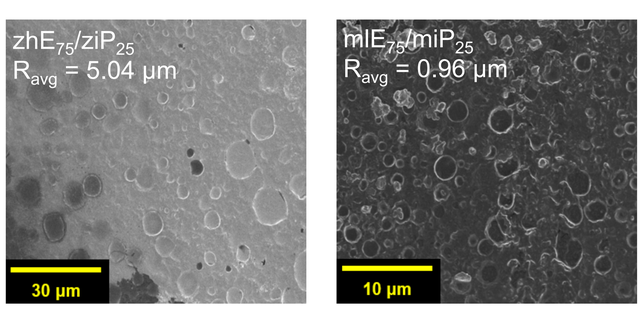






- Droplet-matrix morphology was observed at PE_{75}/PP_{25} and PE_{25}/PP_{75} offset compositions
- Elongated, rod-like droplets were observed in extruded blend sheets

Compression Molded Blends – Imaging



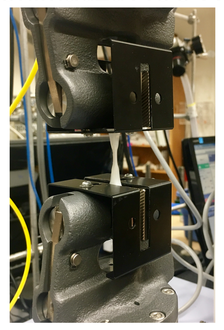
- Droplet-matrix morphology was observed at PE_{75}/PP_{25} and PE_{25}/PP_{75} offset compositions
- Spherical droplets were observed in compression molded samples
- Larger droplet size of R_{avg}=5.04 µm in zhE/ziP blend compared to 0.96 µm in mlE/miP and 1.47 µm in mhE/miP

Methods: Tensile Testing

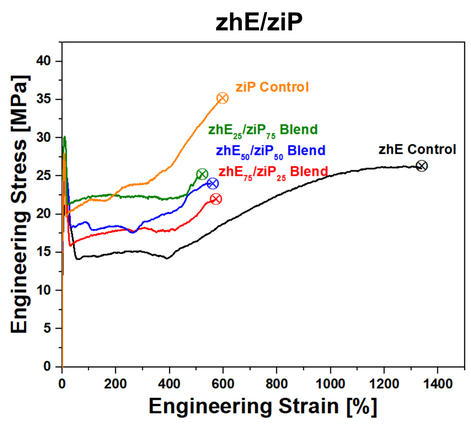
- PE/PP blend samples were molded or cut into a dog bone shape to increase grip and reduce slipping.
- Shimadzu AGS-X tensile tester was used to apply a strain at a rate of 5mm/minute, stress on the sample was recorded.

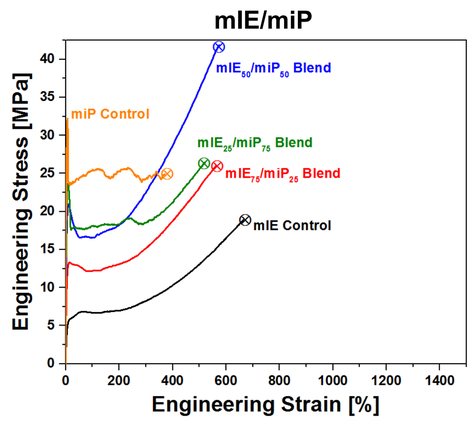
Dog bone Sample

Shimadzu AGS-X

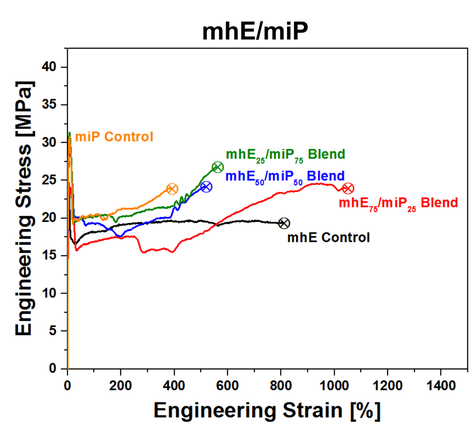


Extruded Blend Sheets – Tensile Data

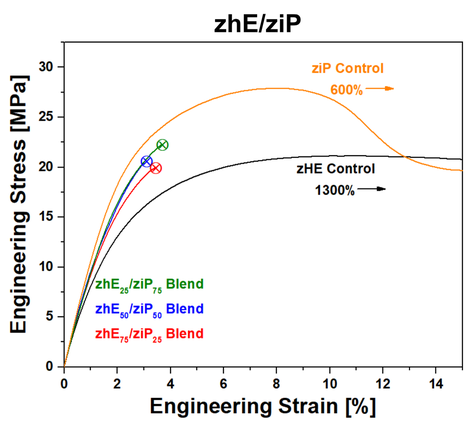


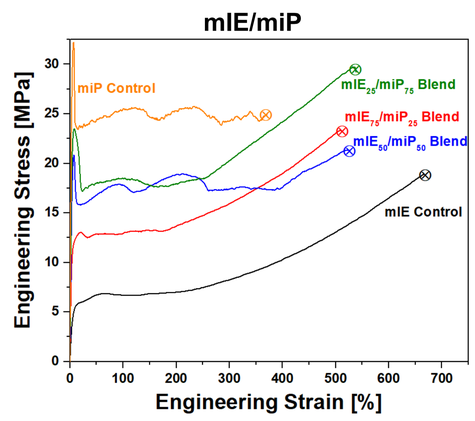


- As polypropylene content increased, yield stress increased and extension decreased
- The modulus increased as polypropylene content increased
- Extension of the blend samples approximately between the extension of the PP control and the PE control for each material

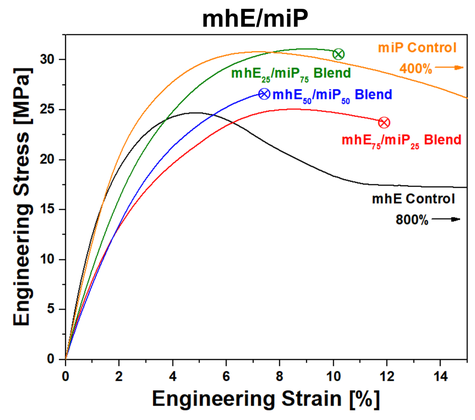


Compression Molded Blends – Tensile Data





- As polypropylene content increased, yield stress increased
- Extension was similar among blend samples of each material
- Extension of the blend samples was lower than PE and PP controls, with the exception of mlE/miP blends
- mlE/miP blends had much greater extension than zhE/ziP or mhE/miP blend samples



Conclusion:

- Extension is greater with extruded blend sheets when compared to compression molded blends.
- This is likely due to the elongated, rod-like droplets that formed during the processing of the extruded samples.
- The spherical droplets that formed in the compression molded blends corresponded to lower sample extension during tensile testing.
- Compatibilized mlE/miP pair showed much larger extension than zhE/ziP and mhE/miP pair.
- The improved mechanical properties of the extruded blends suggest an avenue to recycle mixtures of PE/PP without separating the two polymers.

Acknowledgements:

Imaging by Kyungtae Kim
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References:

[1]F. Galie, *ICIS*. **2016**.
[2]F.S. Bates, M.F. Schulz, J. H. Rosedale, K. Almdal, *Macromolecules* **1992,** *25* (20), 5547-5550.
[3]G.H. Fredrickson, A.J. Liu, F.S. Bates, *Macromolecules* **1994,** *27* (9), 2503-2511.
[4]K.A. Chaffin, J.S. Knutsen, P. Brant, F.S. Bates, *Science* **2000,** *288* (5474), 2187-2190.